SCIENCE FOR CERAMIC PRODUCTION

UDC 666.321

CONCENTRATED KAOLIN FROM THE ZHURAVLINYI LOG DEPOSIT FOR CERAMIC PRODUCTION

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Translated from Steklo i Keramika, No. 1, pp. 15 – 19, January, 2002.

It is demonstrated that the method of dry concentration of kaolin from the Zhuravlinyi Log deposit implemented at the Plast-Rifei Company makes it possible to separate kaolin products of different degrees of dispersion and by mixing them in a certain ratio to control the dispersion, the quality, and the ceramic properties of concentrated kaolin, taking into account the requirements of a particular ceramic production.

The Zhuravlinyi Log deposit of eluvial kaolin located near the town of Plast (Chelyabinsk Region) is operated by the Plast-Rifei JSC. The concentration of kaolin at the enterprise is performed using the dry method, and the annual output is 30 thousand tons.

The concentrated kaolin from Zhuravlinyi Log intended for production of ceramic articles surpasses, in a number of quality parameters, the domestic kaolins from the Eleninskoe and Kyshtymskoe deposits, and in whiteness and mechanical strength it is no worse than the concentrated kaolin from the Prosyanoivskoe and Glukhovetskoe deposits (Ukraine).

It is known that after wet concentration kaolin is not always stable with respect to its dispersion, the residual content of coagulating additives, and, accordingly, its liquescence, mechanical strength, etc., and therefore, in order to ensure stable technological parameters, manufacturers are forced to use two or three kinds of kaolin materials.

In contrast to the wet concentration method, the dry method allows for separation of kaolin products in different stages of the concentration process. Provided that their degree of dispersion is stable, it becomes possible to obtain combinations of these products which would satisfy to a maximum possible extent the requirements of specific ceramics production (household or electrical engineering porcelain, sanitary ware).

The method of dry concentration of kaolin in a closed circuit accepted at the Plast-Rifei Company makes it possible to almost fully extract the useful product in the stage of separation using three units: two centrifugal and a zigzag one. Fractional separation of kaolin product is implemented in cyclones. After the air-kaolin mixture passes through the cyclones, the major part of the kaolin mixture (80%) is deposited there and transforms into a finished product, and the rest passes to the sleeve filters to be deposited there.

The concentration technology provides for the possibility of separating kaolin products after sleeve filters (what is known as filter kaolin) and cyclones (known as cyclone kaolin).

The scheme of separation of kaolin products is shown in Fig. 1.

Filter kaolin products are taken from sleeve filters in the first and the third separation stages (products Nos. 3 and 5), the flue pipeline (product No. 1), and the aspiration system (product No. 6), and cyclone products are taken from the cyclones in the first and the third separation stages (products Nos. 2 and 4).

The coarse-disperse kaolin product (a composite) containing not more than 15% particles sized below 1 μm is not considered as a component for preparation of industrial kaolin product.

The yield of kaolin products in different stages of concentration is indicated in Table 1, whereas Table 2 shows their physiochemical properties. It can be seen that the filter kaolin products resemble each other in their mineral and chemical compositions, whiteness, adsorption capacity, and dispersion. Based on this fact and considering that the share of filter kaolin products in the total balance of materials is insignificant, it appeared possible to combine the filter kaolin products and hereafter consider them as an integrated filter kaolin product (No.7).

The total content of the filter kaolin products (in the material balance) is 8.3%, and that of the cyclone products is

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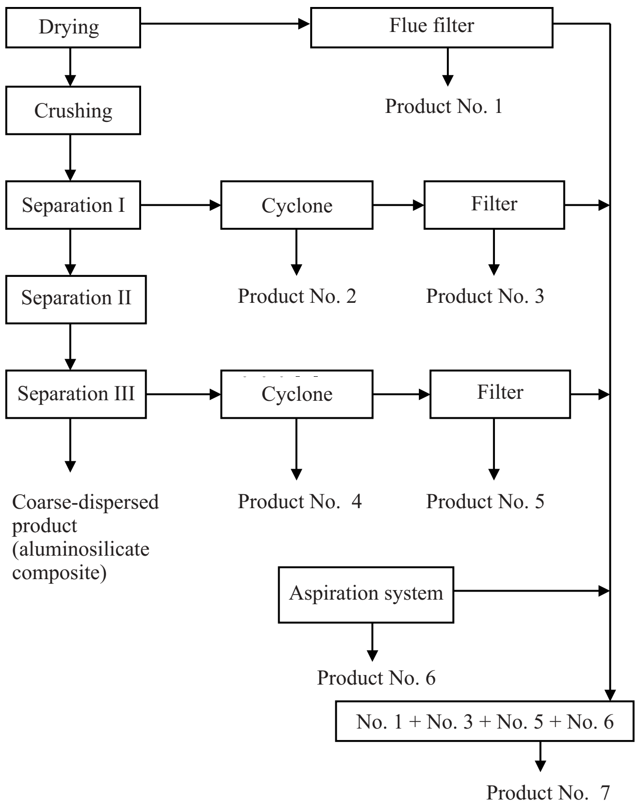

Fig. 1. Scheme of separation of kaolin products (dry concentration).

91.7%, including No. 2 amounting to 65.4% and No. 4 equal to 26.3%. The filter kaolin product is more finely dispersed than the cyclone product and has a higher content of particles sized below 0.5, 1, 2, and 5 μm (Fig. 2).

Filter kaolin product No. 7 has a higher content of kaolinite, aluminum oxide, and a lower content of ferric oxide, which contributes to its better whiteness both in the initial state and after firing at a temperature of 1350°C. The finely dispersed kaolin product has a greater adsorption capacity equal to 25 mg/g, as compared to the cyclone products, whose adsorption capacity is 19 – 21 mg/g.

Cyclone kaolin products Nos. 2 and 4 differ in their dispersion, mainly in their content of fine fractions sized below 0.5 and 1 μm, and insignificantly differ in their content of kaolinite and Al_2O_3 and in their adsorption capacity.

To assess the ceramic properties of the cyclone and filter kaolin products, we determined their whiteness, the mechanical strength of dried and fired samples, their plasticity, shrinkage, liquescence, the rate of mixture setting found based on the gypsum crucible method that characterizes the water yielding capacity, and the filtration properties of the kaolin suspension. The obtained results are shown in Table 3 and in Fig. 3.

TABLE 1

Product	Site of separation of concentrated kaolin	Yield, %
No. 1	Flue pipeline filter	4.9
No. 2	Cyclone of the first stage of separation	65.4
No. 3	Filter of the first stage of separation	2.3
No. 4	Cyclone of the third stage of separation	26.3
No. 5	Filter of the third stage of separation	0.6
No. 6	Filter of the aspiration system	0.5

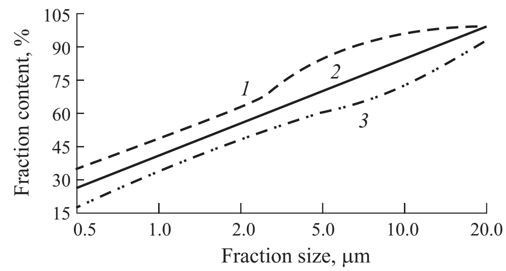

Fig. 2. Degree of dispersion of kaolin products: *1*, *2*, and *3*) products Nos. 7, 2, and 4, respectively.

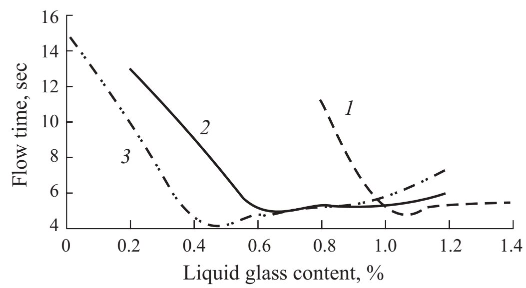

Fig. 3. Liquefying suspensions of kaolin products with moisture equal to 50%: *1*, *2*, and *3*) products Nos. 7, 2, and 4, respectively.

The studies demonstrated that the most dispersed kaolin products (filter product No. 7 and cyclone product No. 2) are characterized by greater values of bending strength (dried and fired samples), higher shrinkage in drying, a greater plasticity number, and higher parameters of whiteness.

It can be noted that as the dispersion of kaolin products increases, the rate of mixture setting and, accordingly, the water yielding capacity decrease. The minimum value was observed in the filter kaolin product whose liquefying requires the greatest amount of liquid glass, compared with other kaolin products. The liquescence was characterized by the dependence of the time of discharge of a suspension from a VZ-246 viscometer on the content of liquid glass.

The kaolin suspension based on the filter kaolin requires 2.7 and 1.75 times more liquid glass to reach a fluidity of 5 sec, than suspensions based on cyclone kaolin products Nos. 4 and 2. The best liquescence is observed in the most disperse product No. 4: a minimum quantity of liquid glass is needed for the suspension based on this product to read a fluidity equal to 5 sec, and this suspension has the lowest thickening coefficient. The highest thixotropic strengthening of the structure is registered in a more finely disperse filter product No. 7; suspensions based on this kaolin have stronger structural bonds and, accordingly, the maximum elasti-

TABLE 2

Parameter	Filter products					Cyclone products	
	No. 1	No. 3	No. 5	No. 6	No. 7	No. 2	No. 4
Residue on a No. 0063 sieve, %			Absent			0.021	0.132
Content of particles, %, of size, μm:							
below 0.5	35.6	36.1	34.2	35.6	34.6	26.0	17.2
below 1	55.1	52.5	48.2	45.1	49.0	41.0	33.0
below 2	65.3	62.5	62.7	63.4	62.9	55.2	48.4
below 5	86.0	86.7	78.6	88.6	84.9	66.9	60.8
below 10	97.7	97.8	96.9	96.3	97.2	84.4	72.5
below 20	100.0	100.0	100.0	100.0	100.0	99.3	93.7
Weight content, %:							
Al_2O_3	37.83	37.88	37.61	38.07	38.31	37.04	36.46
Fe_2O_3	0.35	0.33	0.38	0.40	0.35	0.51	0.63
TiO_2	0.46	0.34	0.32	0.35	0.35	0.29	0.27
$Fe_2O_3 + TiO_2$	0.81	0.67	0.70	0.75	0.70	0.80	0.90
Whiteness, %	81.1	81.0	81.0	80.9	80.5	77.0	75.7
Calcination loss, %	14.50	14.21	14.68	14.41	14.28	13.77	13.31
Adsorption, mg/g	24.0	25.5	23.4	25.5	25.0	21.0	19.0
Mineral composition, %:							
kaolinite	96.0	96.0	97.0	97.0	96.0	92.0	90.0
mica	2.0	1.5	1.0	1.5	1.0	4.5	6.0
quartz	1.5	2.0	1.0	1.0	2.0	3.0	3.5

city modulus and the minimum level of structure-formation threshold (Table 3).

Thus, the ceramic properties of kaolin products (other conditions being equal) are determined by dispersion, i.e., by the content of particles less than 1 μm in size. To plot the dependence of the ceramic properties of kaolin products on their content of particles sized below 1 μm, it was considered convenient to compose two additional mixtures of kaolin products Nos. 2, 4 and 7 with different contents of particles sized below 1 μm. The compositions of composite mixtures containing a prescribed quantity of particles below 1 μm calculated by solving a system of equations by the substitution method are listed in Table 4. Composite mixtures Nos. 1, 3, and 5 are represented by industrial cyclone and filter kaolin products (products Nos. 4, 2, and 7, respectively).

The content of particles sized below 1 μm in the composite mixtures varied within the limits of 33 – 49%. Figure 4 shows the dependences of the whiteness of kaolin products in the initial state, their plasticity number, the bending strength of dried samples, the rate of mixture setting on the wall of a gypsum mold, the amount of liquid glass needed for kaolin suspensions to reach a fluidity of 5 sec, and the shrinkage of samples fired at 1350°C on the content of fine-disperse particles of size not more than 1 μm in the kaolin product.

As the content of fine-disperse particle in kaolin products grows, the plasticity number, the bending strength, and the whiteness increase; and a greater amount of liquid glass is needed to reach a fluidity of 5 sec. As the content of particles below 1 μm in the kaolin suspension increases, the rate of mixture setting on the gypsum mold wall decreases.

TABLE 3

Parameter	Product		
	No. 2	No. 4	No. 7
Bending strength, MPa, of samples:			
dried at 110°C	2.51	1.94	2.81
fired at 1350°C	8.00	71.00	92.00
Shrinkage, %, of samples:			
dried at 110°C	5.7	3.5	6.2
fired at 1350°C	14.1	13.5	19.1
Water absorption of samples fired at 1350°C, %	10.2	11.7	8.8
Plasticity number	6.5	4.8	9.6
Mixture setting rate, g/(cm^2 · sec)	0.008	0.011	0.004
Whiteness of samples fired at 1350°C, %	89.2	86.9	91.8
Amount of liquid glass needed to reach fluidity equal to 5 sec after holding in a viscometer for 30 sec, %	0.6	0.5	0.96
Thickening coefficient	1.8	1.6	2.2
Elasticity index, g/cm^3	0.156	0.106	0.194
Index of structure-formation threshold, g/cm^3	1.134	1.141	1.098

TABLE 4

Composite mixture	Content of particles sized below 1 μm, %	Content of products, %		
		No. 4	No. 2	No. 7
No. 1	33	100	–	–
No. 2	37	50	50	–
No. 3	41	–	100	–
No. 4	45	–	50	50
No. 5	49	–	–	100

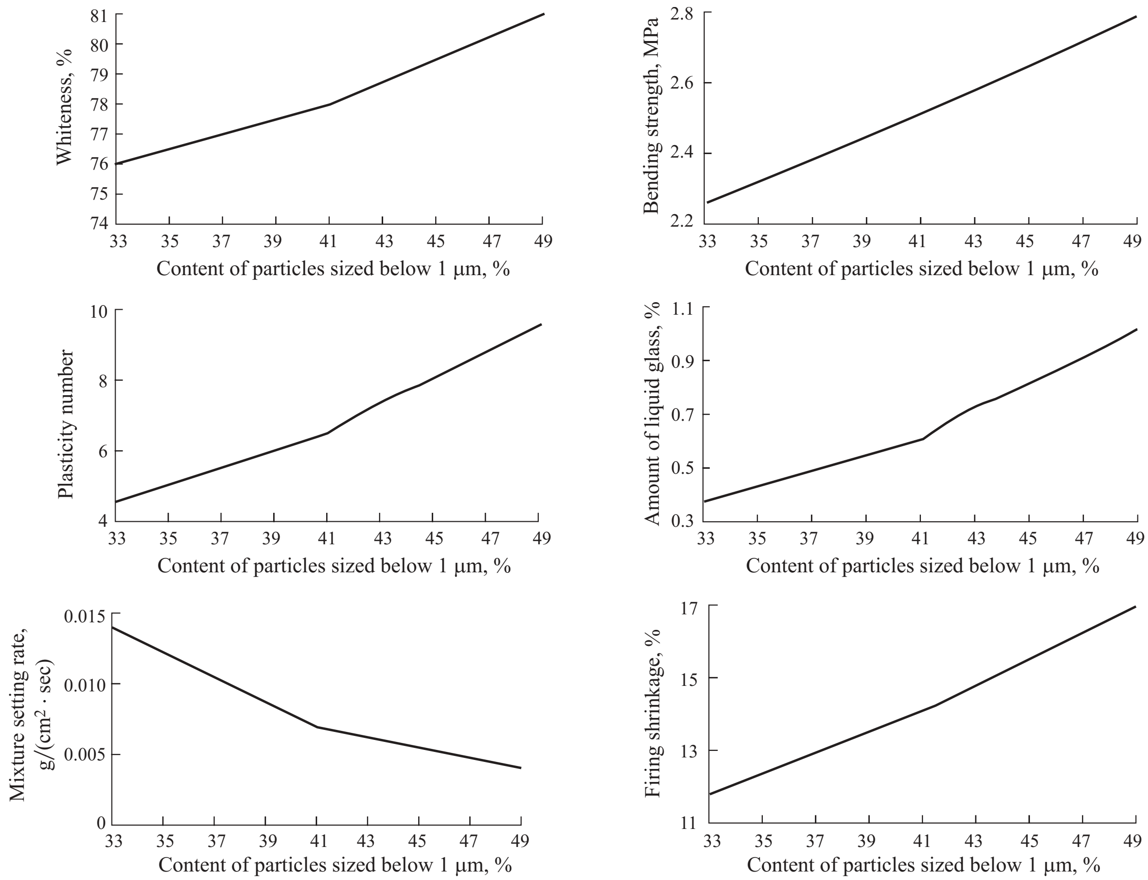

Fig. 4. Ceramic properties of concentrated kaolin depending on the content of particles sized below 1 μm.

Thus, the ceramic properties of kaolin products are determined by their dispersion. Directed control of dispersion by means of mixing kaolin products with a different content of particles below 1 μm in a certain ratio makes it possible to obtain industrial batches of concentrated kaolin with prescribed ceramic properties.

The principle of forming industrial batches of concentrated kaolin for producing household and electrical engineering porcelain and sanitaryware is shown in Fig. 5. The proposed principle is based on a graphic determination of the optimum dispersion interval for concentrated kaolin which would meet the requirements of a particular production imposed on its ceramic properties. The following ceramic properties were taken as determinant ones: whiteness, the amount of liquid glass needed for a kaolin suspension to reach a fluidity of 5 sec, the mixture setting rate, the plasticity number, and the bending strength of fired samples.

The dispersion interval for concentrated kaolin used in producing household porcelain by plastic molding and slip casting is determined by the following requirements: high whiteness, good liquescence and filtration properties, sufficiently high parameters of plasticity (6 – 7) and bending strength (not less than 1.4 MPa). These conditions are satisfied when concentrated kaolin contains 41 – 44% particles of size below 1 μm. Within the specified dispersion interval, the plasticity number of kaolin meets the requirements (6.3 – 7.2), and the amount of liquid glass for liquefying does not exceed 0.7%, which makes it possible to obtain satisfactory casting properties for using the slip technology. The concentrated kaolin in this case has a high rate of mixture setting and high bending strength (2.5 – 2.6 MPa) and whiteness (76.5 – 78.2%). Industrial batches of such kaolin mainly consist of cyclone kaolin product No. 2 from the first stage of separation with an addition of not more than 35% of the filter kaolin product.

Production of articles from electrical engineering porcelain (the method of plastic molding with preliminary filter-pressing of a ceramic mixture) requires concentrated kaolin with a high filtration capacity, good liquescence, and a plasticity number interval of 5 – 6. These requirements are met in concentrated kaolin containing 35 – 41% particles sized below 1 μm. Kaolin within the specified dispersion interval has satisfactory values of whiteness (76.0 – 77.5%) and bending strength (2.3 – 2.5 MPa).

The industrial batches of concentrated kaolin for electrical engineering porcelain contain cyclone kaolin product No. 2 from the first separation stage and up to 75% of cyclone kaolin product No. 4 from the third stage of separation.

Ceramic sanitaryware is produced by slip casting in gypsum molds; therefore, the main requirements imposed on

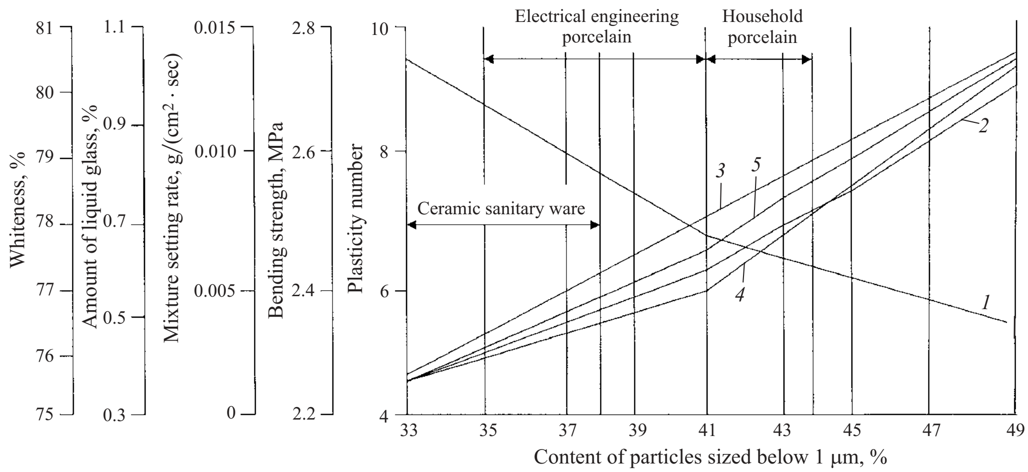

Fig. 5. Optimum dispersion intervals for concentrated kaolin from the Zhuravlinyi Log deposit intended for ceramic production: *1*) mixture setting rate; *2*) amount of liquid glass; *3*) bending strength; *4*) whiteness; *5*) plasticity.

concentrated kaolin, whose plasticity number should not be below 4.5 and over 6.0, include satisfactory liquescence and a high rate of mixture setting on a gypsum mold wall. As can be seen in Fig. 5, the concentrated kaolin containing 33 – 38% particles below 1 μm meets the specified requirements. In this case the kaolin has lower whiteness (up to 76.5%) and a sufficiently high bending strength in the air-dried state (not less than 2.2 MPa).

The industrial batches of kaolin for sanitaryware mostly use cyclone kaolin product No. 4 from the third stage of separation adding up to 60% of cyclone kaolin product No. 2 from the first stage of separation.

Thus, the method for dry concentration of kaolin from the Zhuravlinyi Log deposit implemented at the Plast-Rifei company makes it possible to separate kaolin products of different degrees of dispersion and by mixing them in a prescribed ratio to control the dispersion, quality, and ceramic properties of concentrated kaolin, taking into account the requirements of a particular production.

A technical standard has been developed for concentrated kaolin from Zhuravlinyi Log based on the above described possibilities of the dry concentration technology.

According to TU 5729-0090-00284530–00 standard, the company produces four grades of concentrated kaolin from Zhuravlinyi Log intended for ceramic production: KZhF-1, KZhF-2, and KZhÉ for household and electrical engineering porcelain and KZhS for ceramic sanitaryware. The kaolin of each grade is characterized by a particular degree of dispersion and by stable quality and ceramic properties.